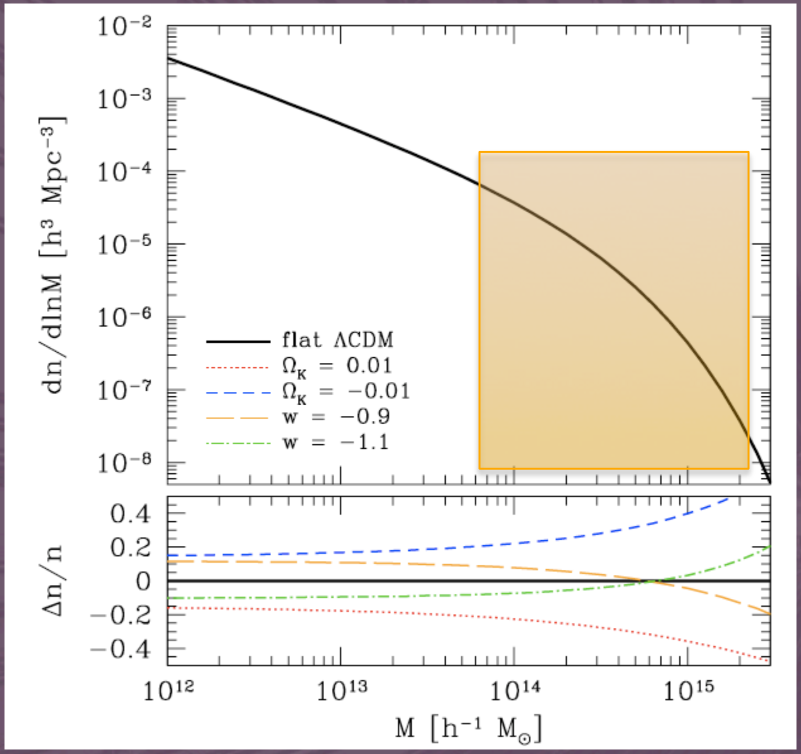
Cluster cosmology with stacked weak lensing



Cluster abundance constrains $\sigma_8(z)\Omega_m^{\,q}$ with $q \approx 0.4$.

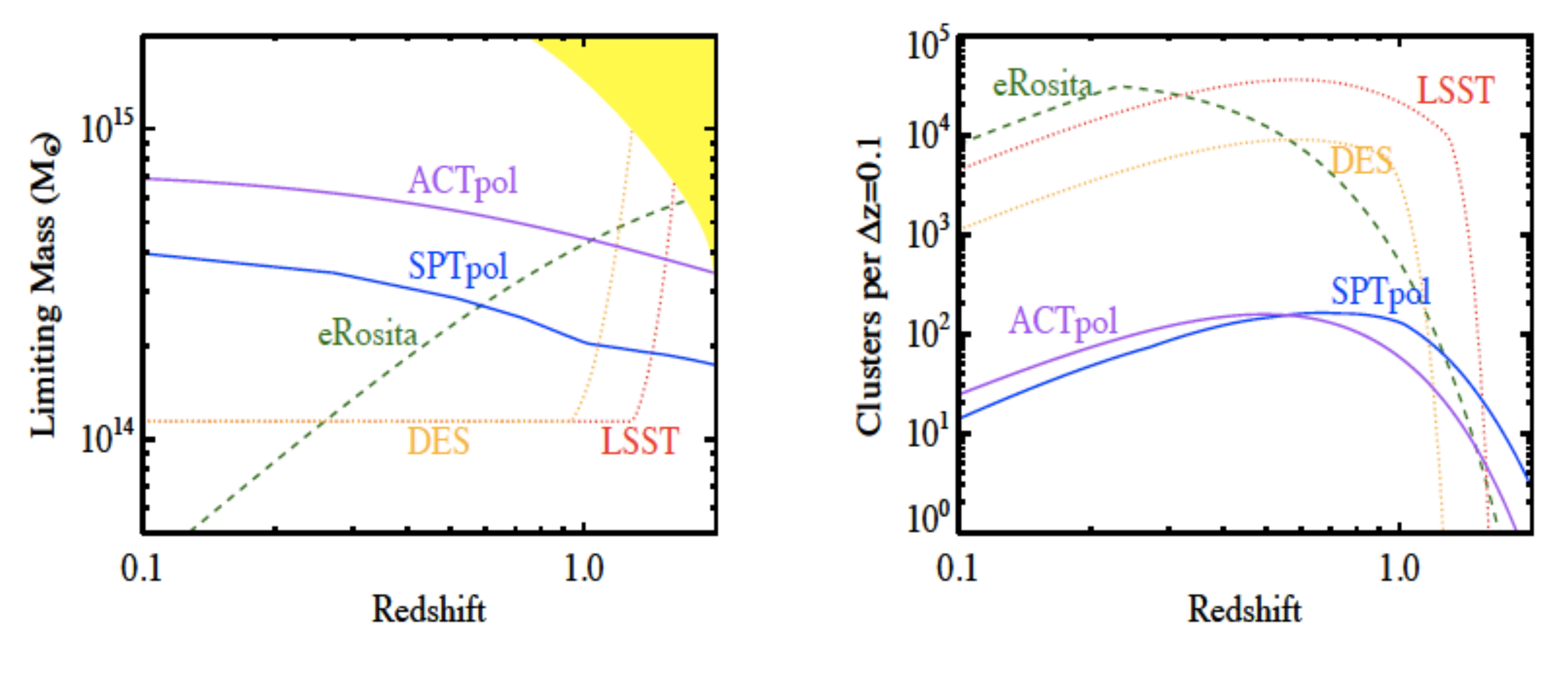
Abundance errors from counting statistics are very small.

The key limitation is systematic uncertainty in mass calibration.

Most promising approach: stacked weak lensing.

Basic requirements for cluster cosmology tests

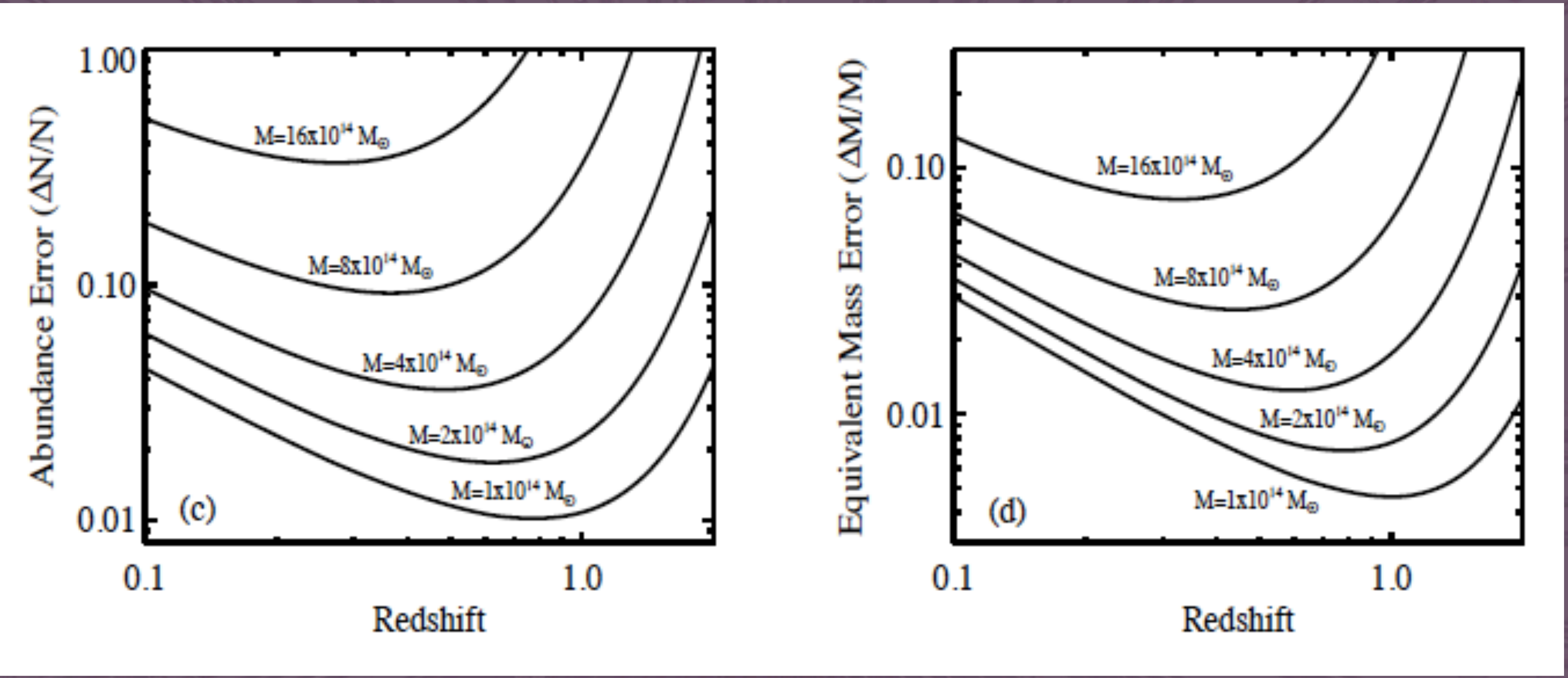
- Find them.
  - WFIRST + optical imaging (LSST, other)
  - eRosita X-ray



Basic requirements for cluster cosmology tests

- Find them.
    - WFIRST + optical imaging (LSST, other)
    - eRosita X-ray
- Count them. Understand completeness and contamination.
- Calibrate the observable-mass relation, the probability P(O|M) of observable O given true mass M.
    - Mean relation. Stacked weak lensing.
    - Scatter. Well observed sub-samples; clustering; simulations. Tighter P(O|M) means weaker demand on knowledge of scatter.
    - Tails. Simulations. Internal consistency checks.
- Predict the observables as a function of cosmological parameters. Potential systematic uncertainty, e.g., baryonic effects on mass profiles.

Errors in abundance per $\Delta z = 0.1$ for a 10^4 deg^2 survey



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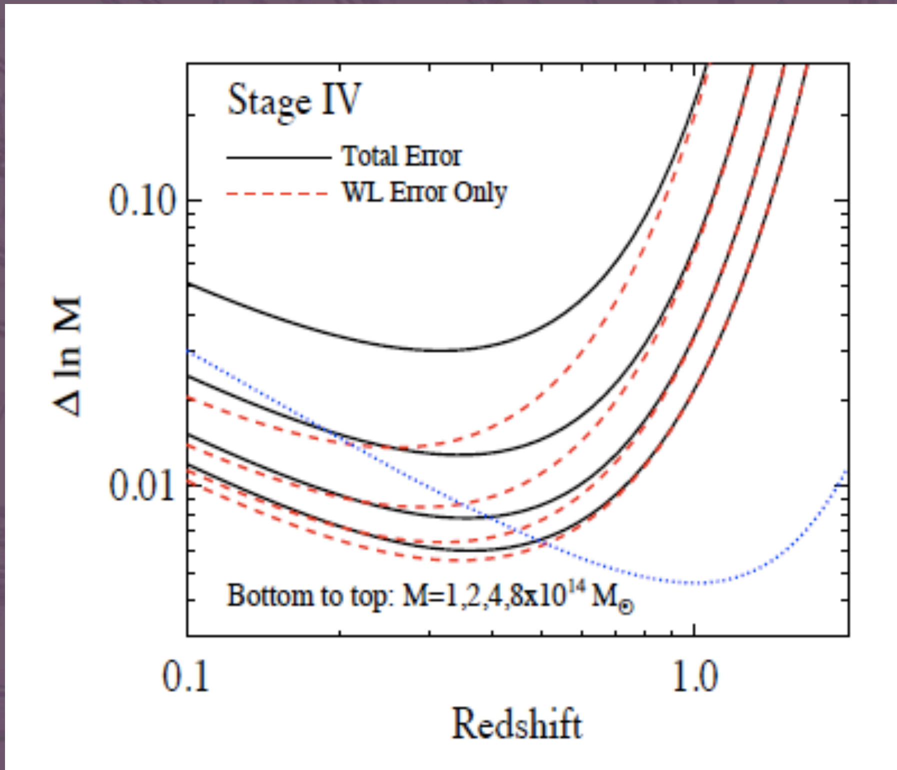
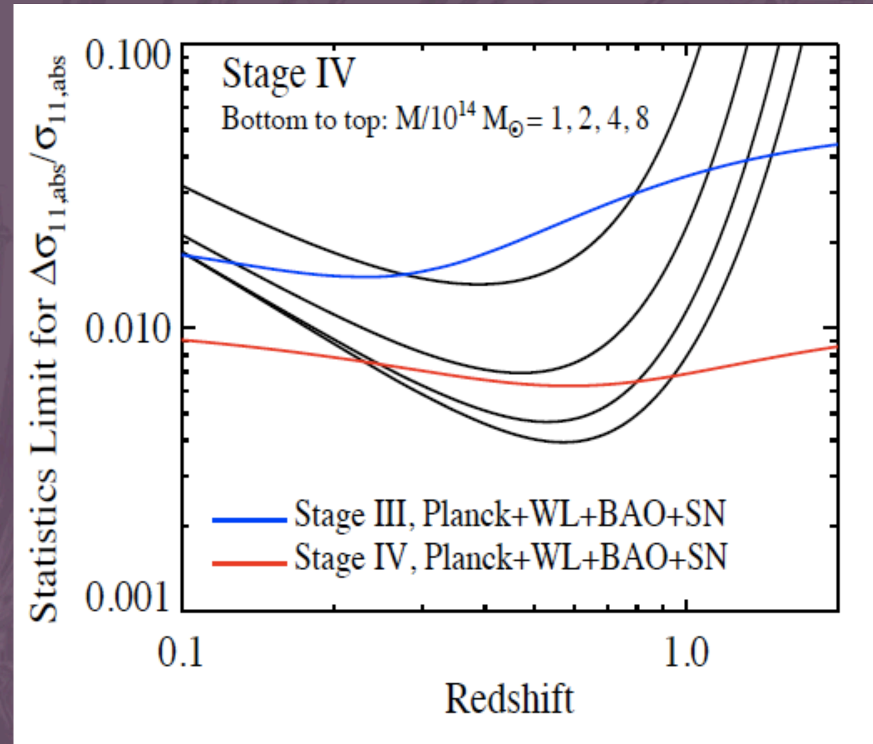




Mass calibration error achievable with stacked weak lensing in 10^4 deg^2 if limited by shape noise statistics.

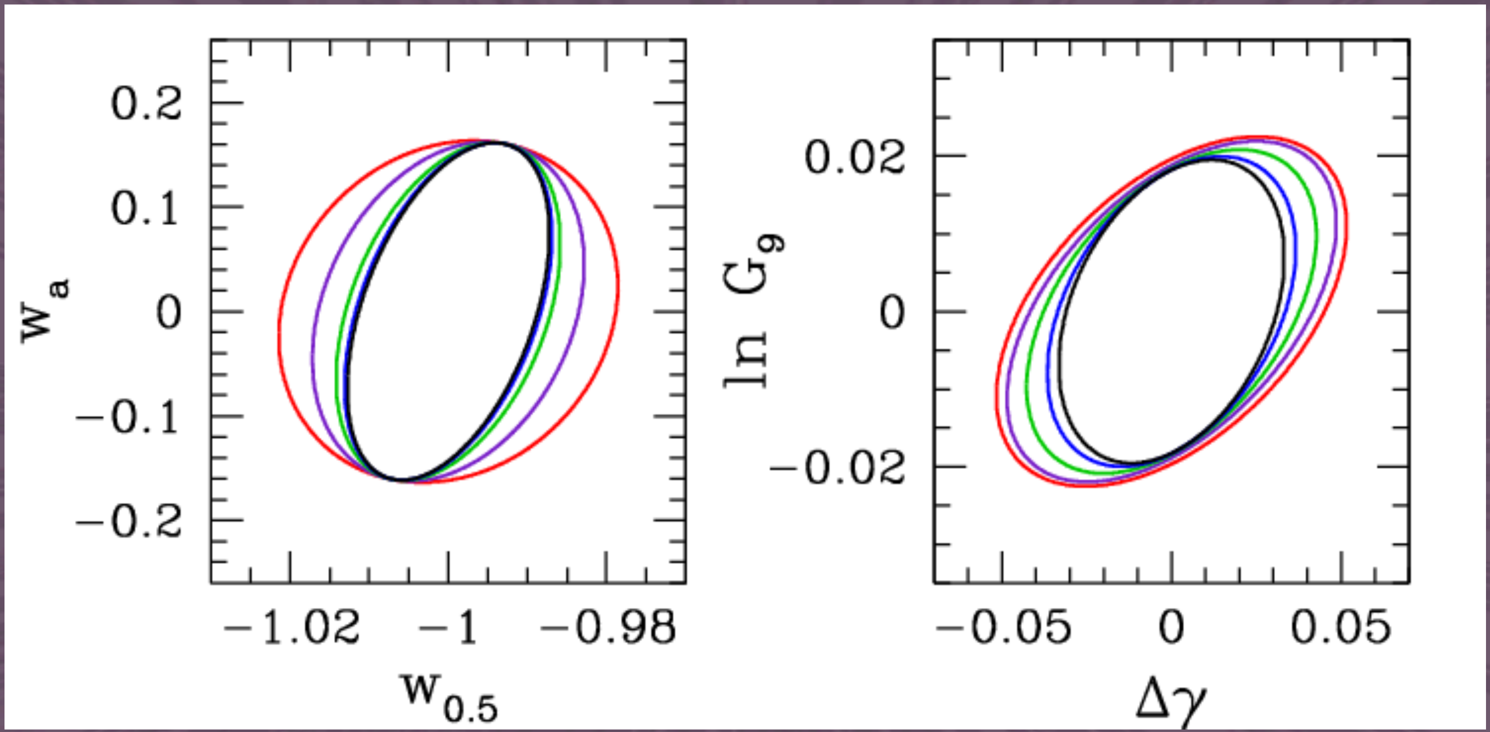
Left: "Stage IV" weak lensing, $n_{eff} = 30$ arcmin^{-2}, $\sigma_e = 0.3$

Blue: Error from cluster counting statistics only, 10^{14} $M_{sun.}$

Right: Corresponding error on matter fluctuation amplitude.

All errors scale as (Area)$^{-1/2}$.

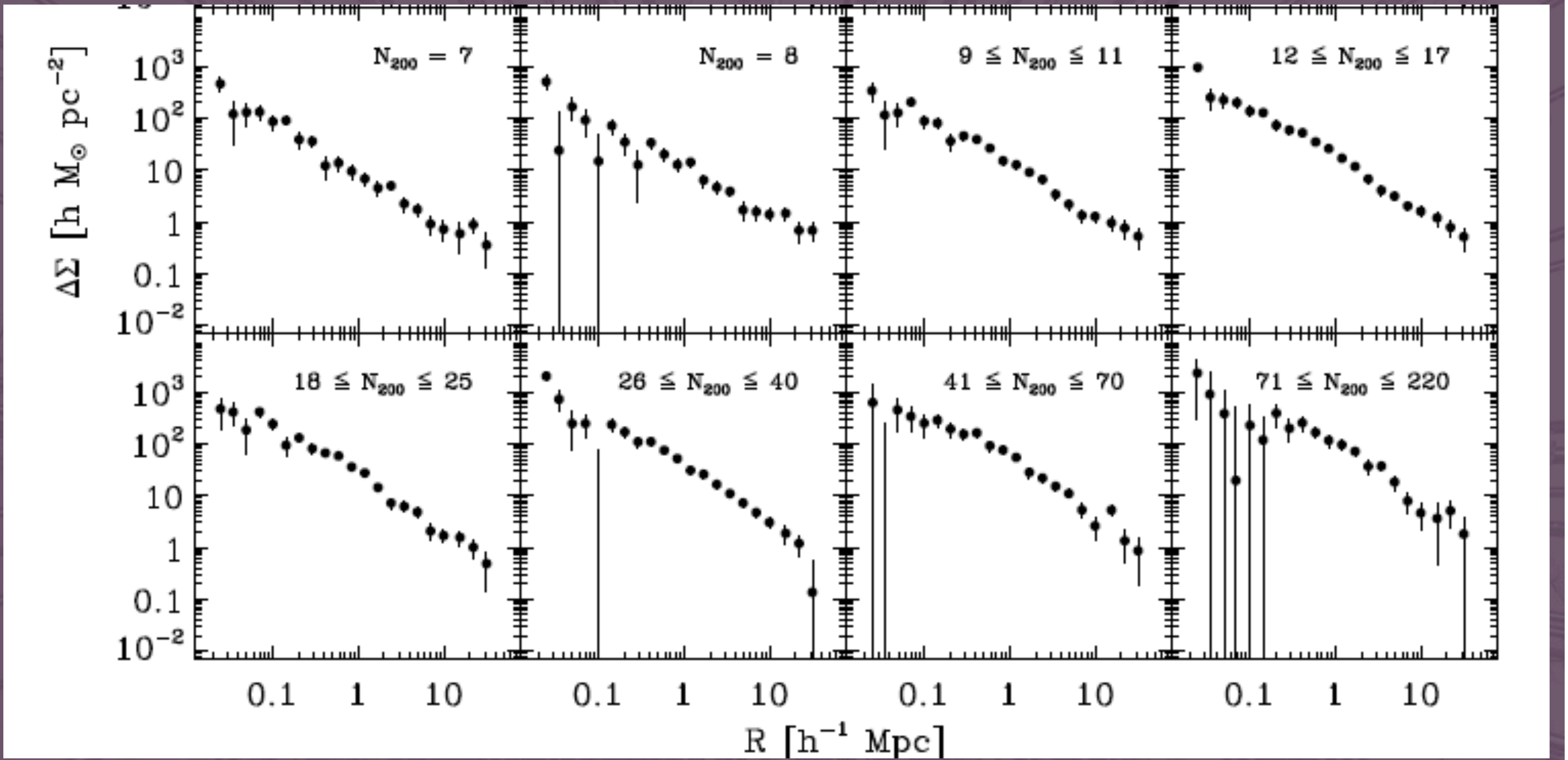
Adding Clusters to fiducial SN+BAO+WL+CMB



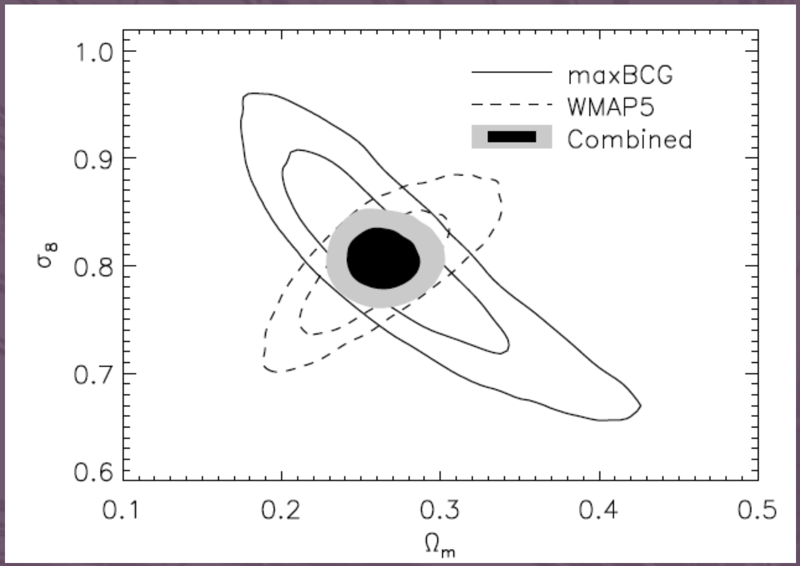
10^4 deg^2 cluster survey with stacked WL mass calibration (n_{eff} = 30 galaxies/arcmin^2)

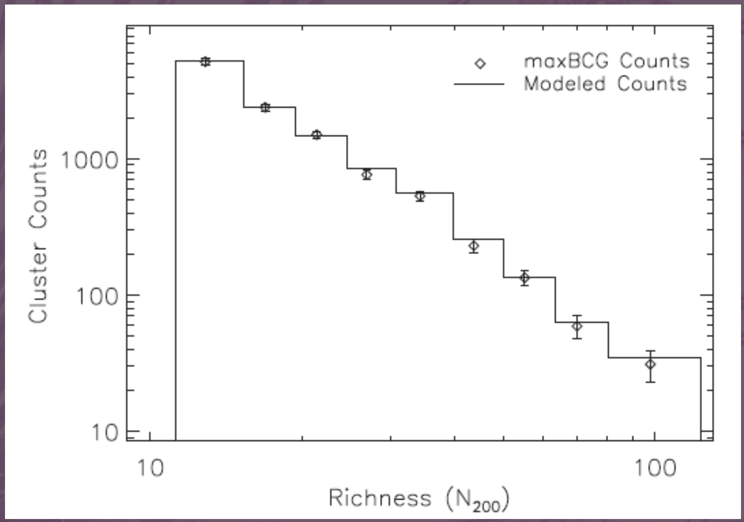
without clusters
$M_{min} = 8 \times 10^{14}\ M_{\odot}$
$M_{min} = 4 \times 10^{14}\ M_{\odot}$
$M_{min} = 2 \times 10^{14}\ M_{\odot}$
$M_{min} = 1 \times 10^{14}\ M_{\odot}$

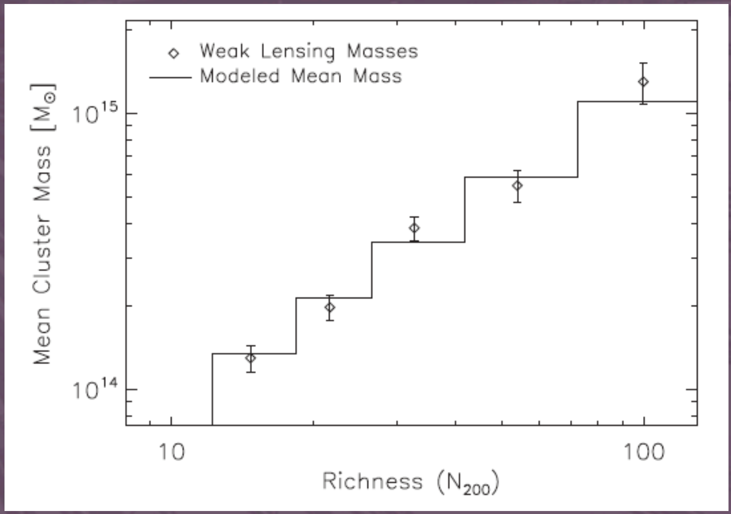
Sheldon et al. 2009



Catalogs of 10,000+ galaxy clusters identified from SDSS images. Precise average mass profiles measured via cluster-galaxy weak lensing.







Cluster mass function

Rozo et al. 2010:

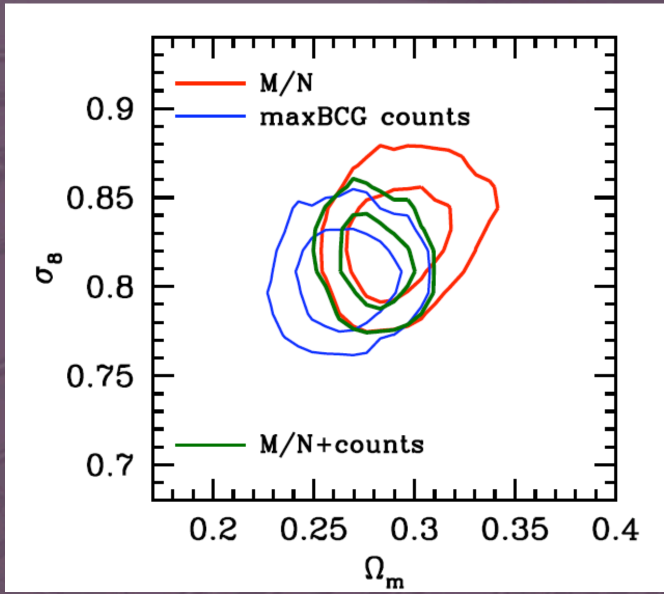
Combine space density of clusters with mean weak lensing mass, both as function of richness. Yields tight parameter constraints and consistency test of ΛCDM + General Relativity:

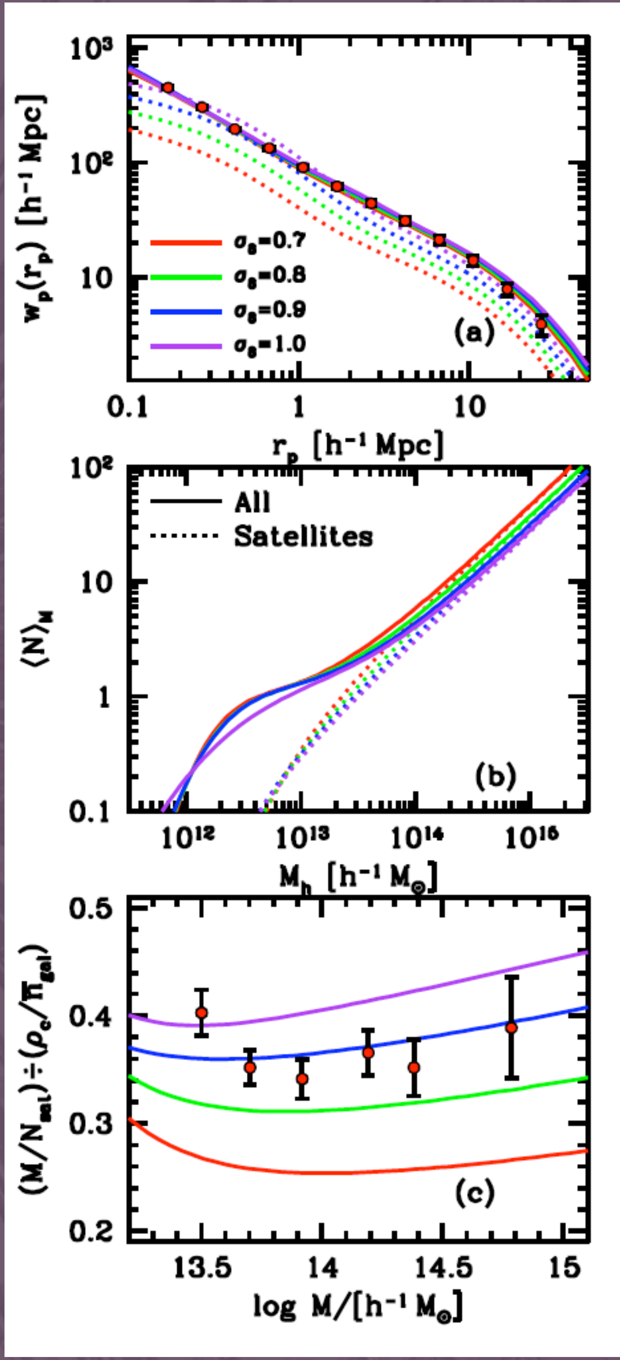
$\Omega_m = 0.265 \pm 0.016$, $\sigma_8 = 0.807 \pm 0.020$

Cluster mass-to-number ratios

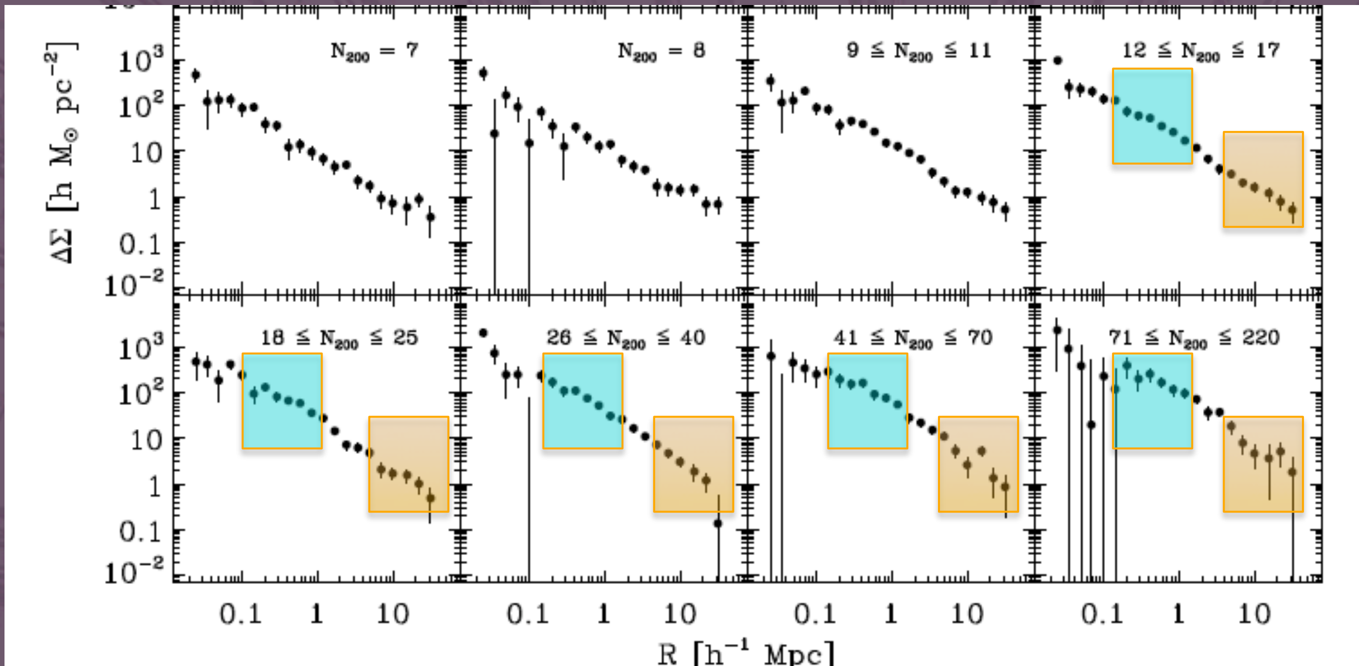
Joint fit of HOD model to galaxy correlation function (SDSS DR7) and M/N_{gal} ratios of maxBCG clusters, with stacked weak lensing masses.

Higher M/N for higher σ_8 or Ω_m .

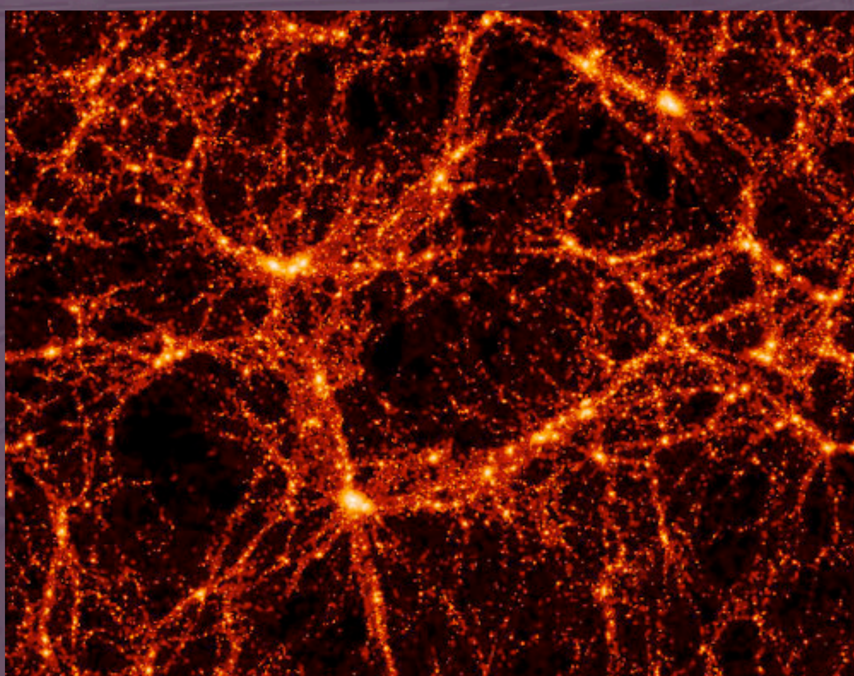




Tinker, Sheldon, Wechsler et al. 2011

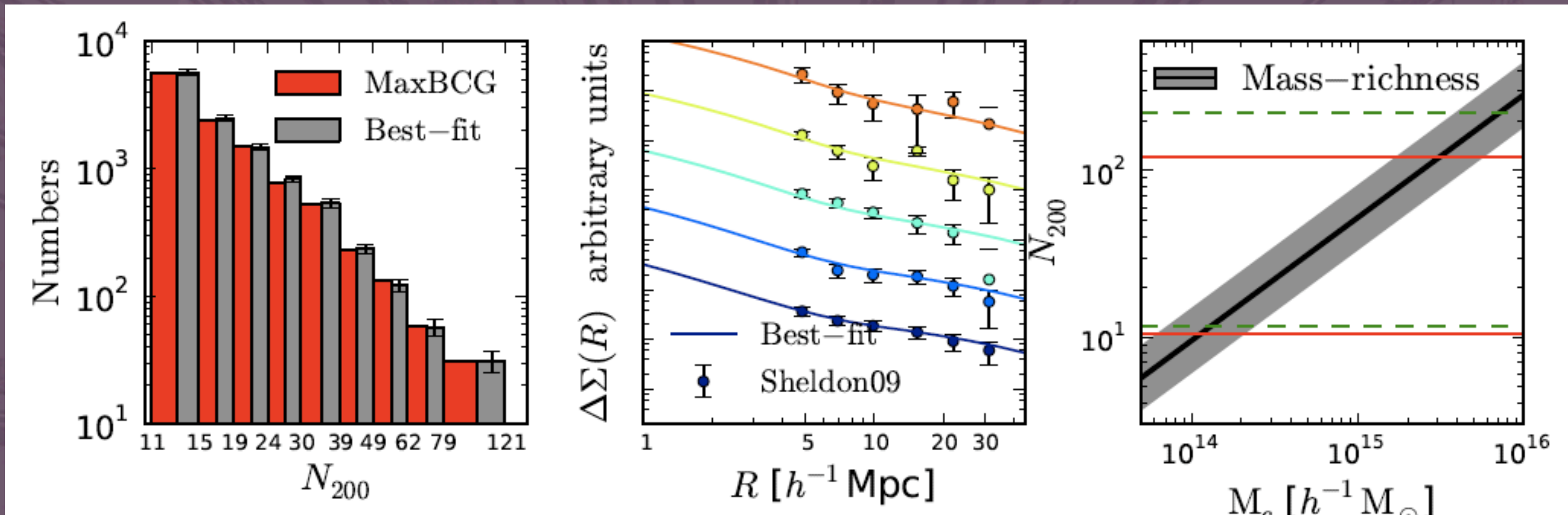


Sheldon et al. 2009

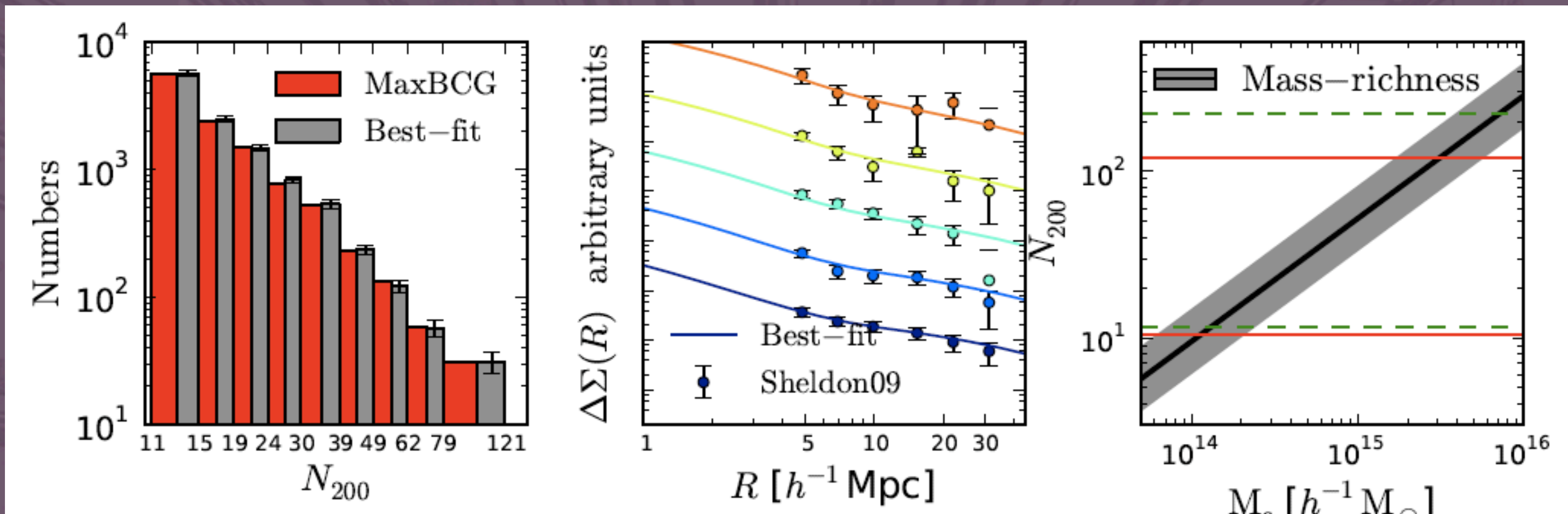


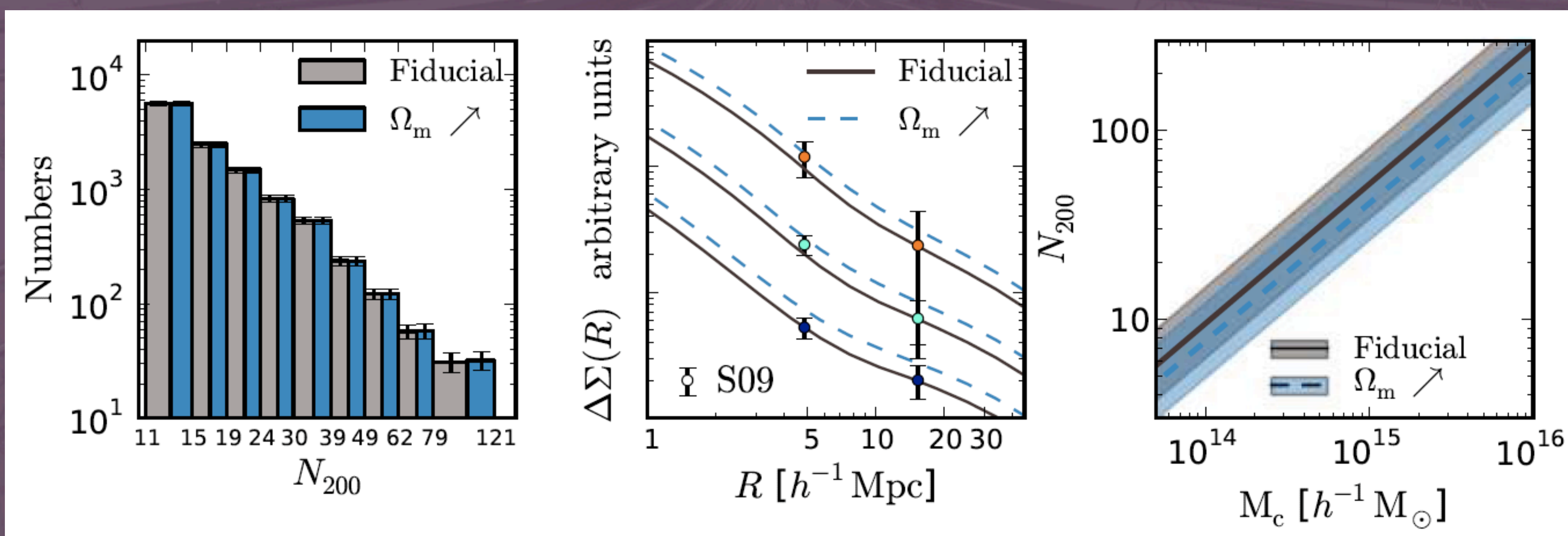
Virgo consortium

Ying Zu, D. Weinberg, E. Rozo, E. Sheldon, J. Tinker, M. Becker 2012

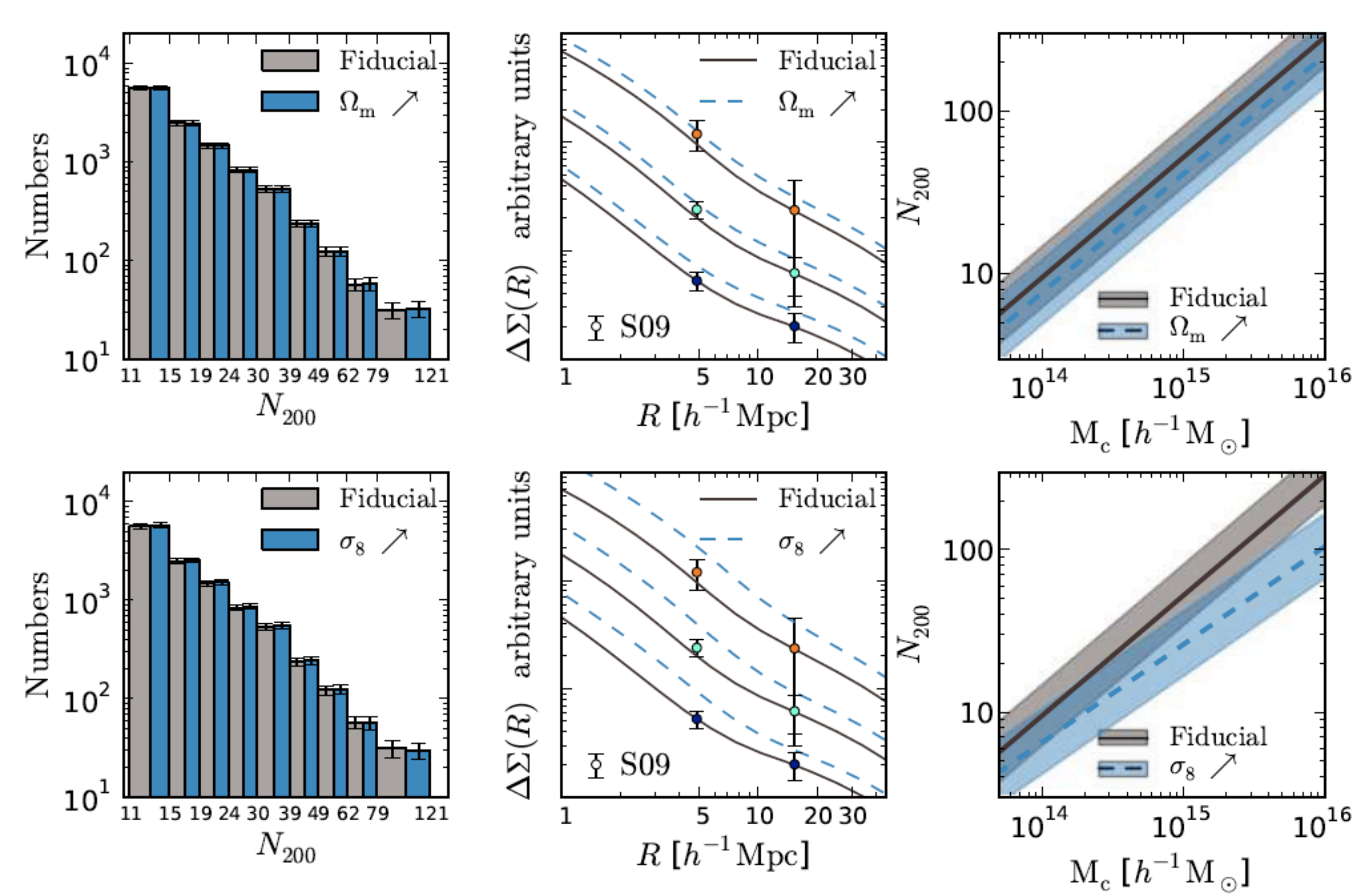


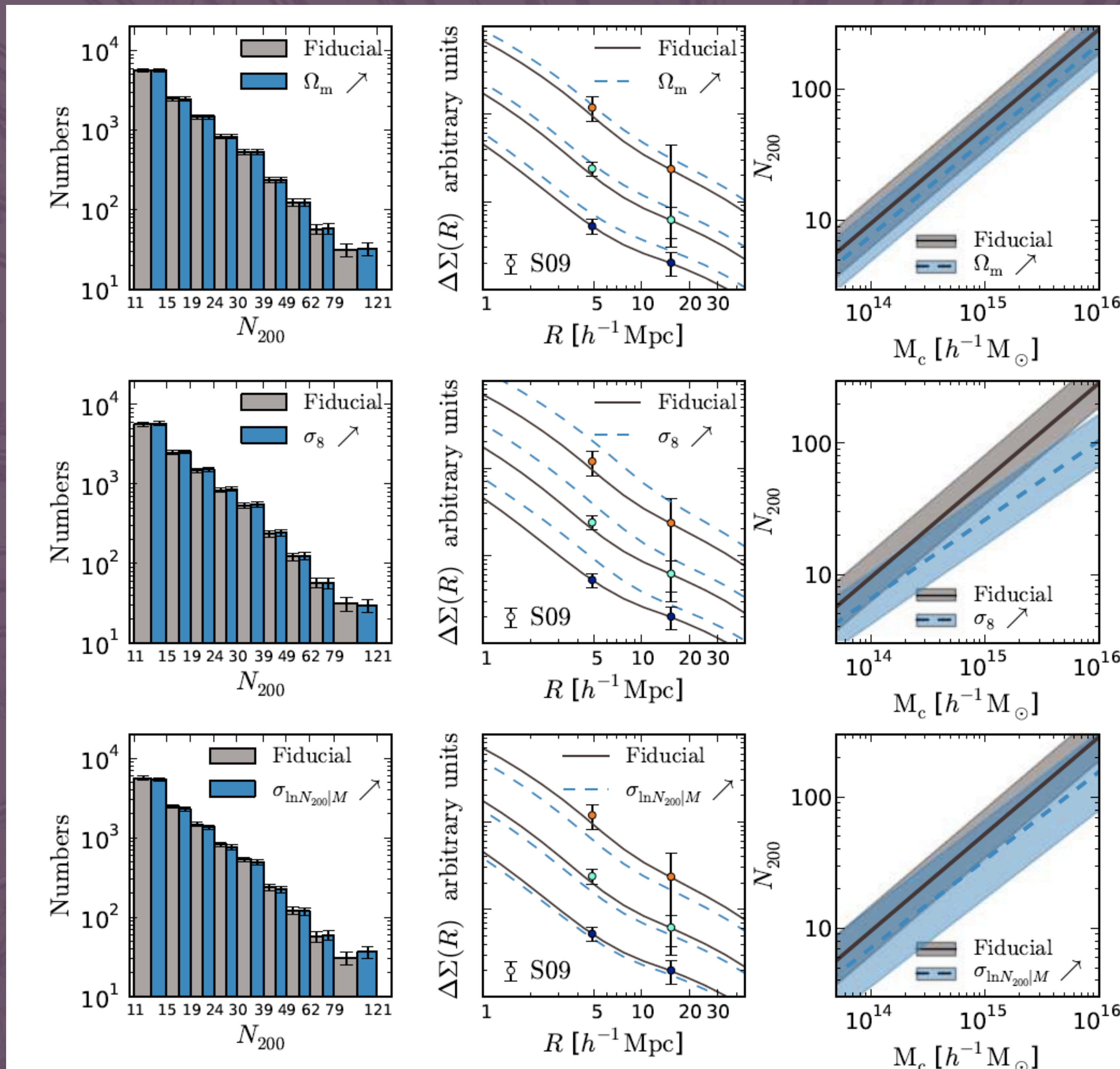
Ying Zu, D. Weinberg, E. Rozo, E. Sheldon, J. Tinker, M. Becker 2012





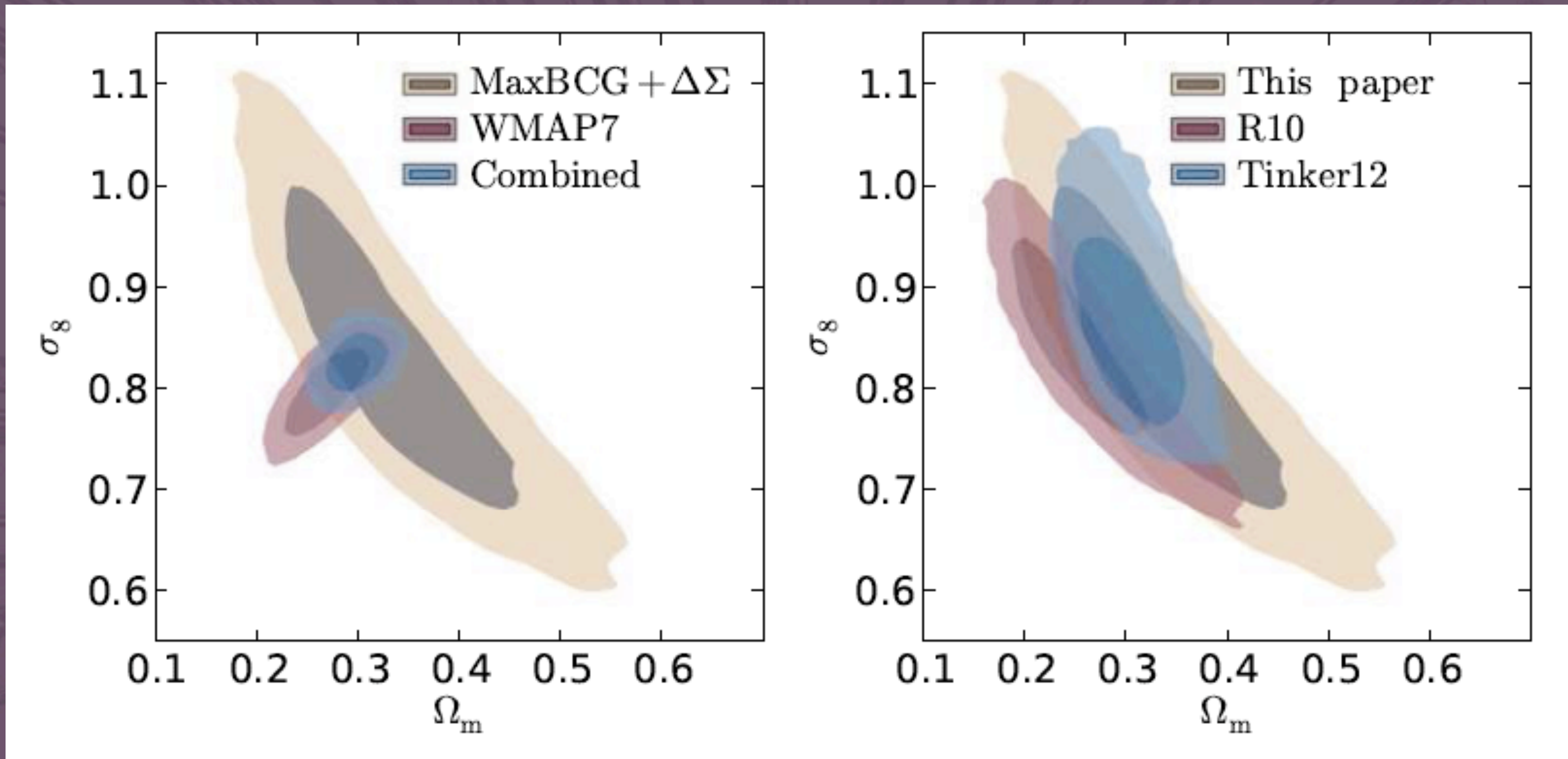
Ying Zu, D. Weinberg, E. Rozo, E. Sheldon, J. Tinker, M. Becker





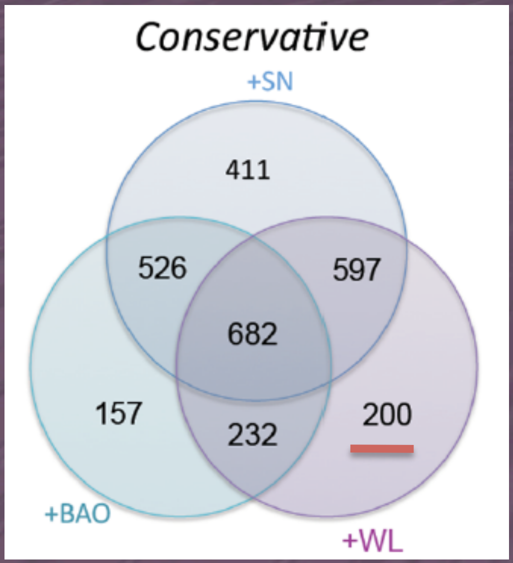
Numbers
N_{200}
Fiducial
Ω_m ↗
σ_8 ↗
$\sigma_{\ln N_{200}|M}$ ↗
$\Delta\Sigma(R)$ arbitrary units
R [h^{-1}Mpc]
S09
N_{200}
M_c [$h^{-1}M_\odot$]

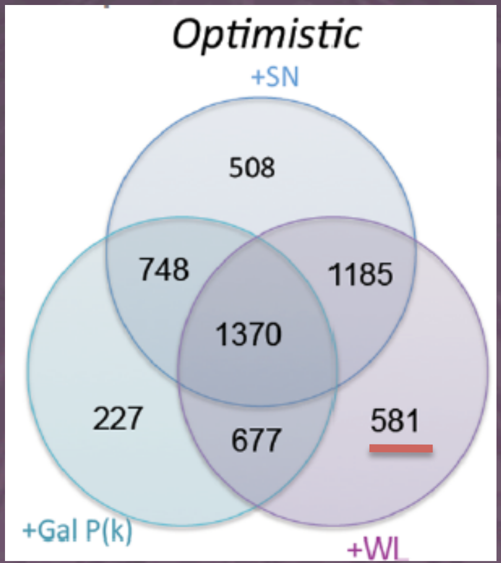
Ying Zu, D. Weinberg, E. Rozo, E. Sheldon, J. Tinker, M. Becker 2012



Conclusions

• Cluster-galaxy weak lensing should significantly increase the return from the WFIRST WL survey.
• Small scale: halo mass function.
• Large scale: halo-mass correlation function.
• No new operational requirements. Probably easier technically than cosmic shear.
• Special case of galaxy-galaxy lensing, which has still greater potential for improving the cosmic acceleration constraints.





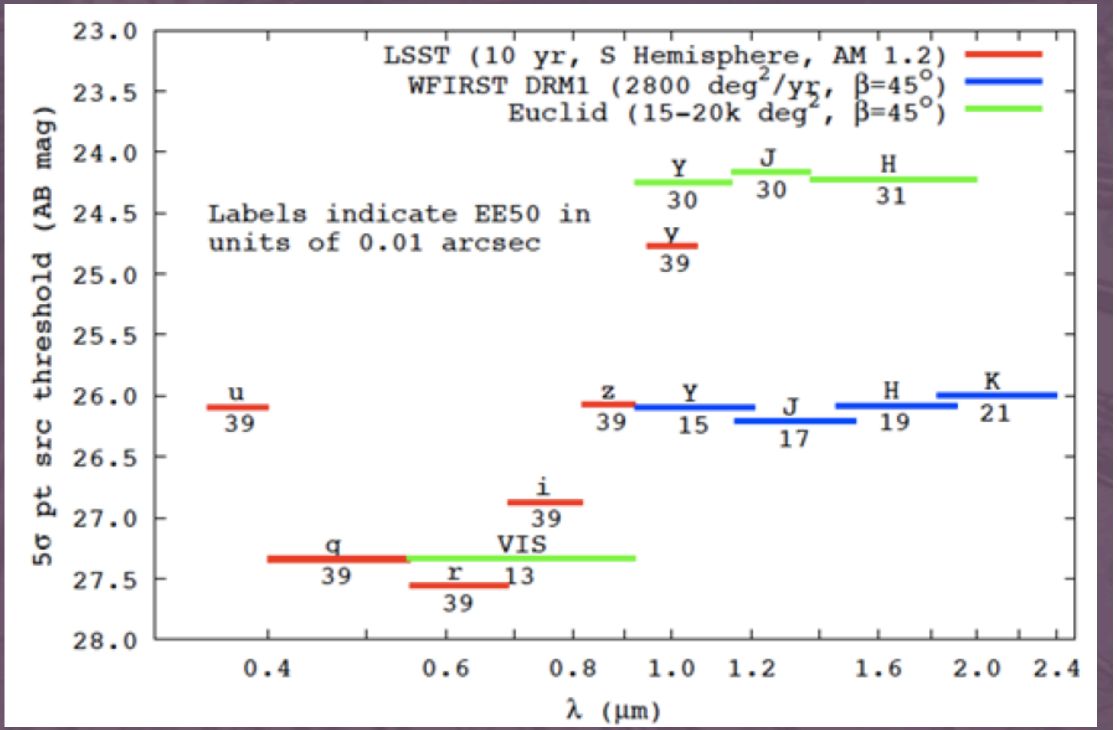
DRM1 forecasts: biggest difference for WL is galaxy-galaxy lensing.

Combining WFIRST and LSST

Combination of the two data sets allows:

- Much better photo-z's (optical+IR essential for WL)
- Cross-correlations of shear maps from two very different instruments. Great cross-checks (but have to decide what to do if they disagree).
- Much better galaxy science: high-res images over long wavelength range, and spec-z's for some gals.

2.4m should allow depth better matched to LSST.



WFIRST SDT Report
Green et al. 2012